

## REMARKS

In the final Office Action mailed October 9, 2002, claims 14 to 18 have been rejected under 35 U.S.C. 112, first paragraph, because the phrase "layered heterojunction" does not find enabling support in the disclosure, and is inconsistent with figure 2, and with the content of amended claim 1.

First of all, the Applicants wish to thank the Examiner for this constructive remark. Indeed, whereas at the macroscopic level the heterojunction comprises layers, figure 2 discloses that at the microscopic level the sensitizing particles 7, the electron conductive particles 6 and the hole conductive particles 8 are mixed together in an interface transition region, and moreover the resulting heterojunction comprises a plurality of individual point-contact-type heterojunctions instead of a single layered type one.

In view of the above, the objected term "layered" has been removed from claims 14, 15, 16 and 17. It is submitted that the claim rejection under 35 U.S.C. 112 is thereby rendered moot.

Furthermore, claim 1 has been amended so as to recite the feature that the Examiner pointed out as being an essential disclosure of figure 2. It is therefore submitted that this further amendment of claim 1 does not introduce any fresh matter going beyond the initial disclosure, that it does not raise up any new issue and that it permits claim 1 to more precisely define the claimed invention.

In the second paragraph, page 8, of the final Office Action, the Examiner pointed out that the recitation "a form of particles adsorbed at the surface of said electron

conductor" does not necessarily have the meaning that the particles are individual. The amended claim language now recites this feature. The Applicants submit that since this matter was thoroughly discussed in previous papers, this amendment does not raise up any new issue.

Amended claim 1 further recites that the sensitizing particles are quantum dots. Since this feature was previously recited in claim 4, the amendment does not raise up any new issue and defines more precisely the claimed invention.

Finally, amended claim 1 recites that:

- the electron conductor is in the solid state; this is clearly based on the whole specification and can not raise up any new issue;
- the hole conductor is in the solid state; this feature was previously present in claims 8 and 9; and
- the sensitizing particles are in form of quantum dots.

Thus, the physical states of the three components of the heterojunction are precisely defined in amended claim 1.

Turning now to the claim rejections under 35 U.S.C 102, under item 9 of the final Office Action, the Examiner discusses the teaching of figures 1 to 4 of the Vogel reference, and in particular the effect of the number of deposition treatments on the particle size and the IPCE.

The Examiner has accurately noted, in view of figures 1b, 1c and 1d of the Vogel reference, together with the corresponding disclosure on page 243, left column, lines 5 to

10, of this reference, that electrodes coated 5 to 10 times bear individual quantum dot particles, whereas an electrode coated 30 times (figure 1d) bears larger clustered aggregates, which obviously can no more be termed as quantum dots. In the final Office Action, bridging pages 3 and 4, the Examiner raises the question of what could be the state of electrodes submitted to an intermediate number of dipping and coating treatments of about 20 or between 20 and 30.

Figure 1 of the Vogel reference does indeed not show microphotographs of electrodes coated about 20 times. However, from figure 3 of the Vogel reference and the corresponding description, on page 245, left column, it appears that the IPCE value increases at least up to 5 coatings. For an electrode coated 10 times, a slight IPCE decrease takes place, and for electrodes coated 20 times and 30 times, a strong decrease of the IPCE is observed. It appears therefore from the combined teachings of figures 1 and 3 that up to 10 coating treatments the electrodes bear individual quantum dot particles. However, electrodes coated 20 times do no longer bear quantum dots. Whereas the Vogel reference does not explicitly teach that after 20 treatments the particles are already clustered or aggregated, nevertheless, the strong decrease of the IPCE after 20 coatings shown by figure 3 clearly demonstrates that these particles have already grown to a dimension outside the quantum size.

This is clearly in accordance with the knowledge of those skilled in this specific art; namely, that nanometer-sized particles of inorganic semi-conductors are a specific class of low-dimensional materials with specific optical and electronic properties. When the size of the nanocrystal is smaller than that of the exciton in the semi-conductor, the lowest energy optical transition is significantly increased in energy due to quantum

confinement. The absorption and emission energy can thus be tuned by changing the size of the nanocrystal. For example, by changing the size from 6 nm to 2 nm, the energy gap can be tuned from 2.6 to 3.1 eV in CdS and from 2.0 to 2.6 eV in CdSe (see also, for example, the introductory part, right column, page 241, of the Vogel reference). These specific properties only exist in the nanometer range, that is to say, roughly speaking, between 1 and 10 nm.

In summary, the Applicants submit that indeed the Vogel reference studies and discusses the properties of CdS particles between 4 and 20 nanometers, as outlined in the abstract of the reference. The reference also clearly demonstrates that quantum dot properties are present in particles of less than 10 nm, such particles being obtainable by a number of coating processes of between about 1 to 10, and that quantum dot properties no longer exist within coatings obtained by a number of dipping and coating processes of 20 and more.

In other words, since Siebentritt et al. expressly teaches to repeat the dipping and coating process between 20 and 40 times, leading to crystallites of 20 nm and more, and embedded moreover in amorphous matrixes, the resulting semi-conductor in Siebentritt et al. **can not be** in the form of quantum dot particles.

Thus, the Applicants submit that the subject matter of amended claim 1 is undoubtedly novel over Siebentritt et al.

Turning now to the non-obviousness of amended claim 1 over Siebentritt et al. in view of Vogel, and also to the rejection of claim 18 under 35 U.S.C. 103, on page 7 of the final Office Action, the Examiner considers that although Siebentritt et al. does not

expressly disclose that the deposition treatment for the particles can be performed 2 to 10 times, it would have been obvious to one of ordinary skill in the art to make the solar cell of Siebentritt et al. with the deposition treatment for the sensitizing particles being performed 5 or 10 times, per the teachings of Vogel, so that a solar cell with high IPCE would be achieved. The Applicants respectfully traverse this reasoning.

Vogel indeed teaches to produce quantum dots on a  $\text{TiO}_2$  substrate by means of a coating process repeated a few times, typically five times. The Vogel reference further teaches that if the coating process is repeated more than 20 times, typical quantum size effects disappear.

Nevertheless, having due knowledge of the Vogel reference, the later Siebentritt et al. reference teaches that in order to make specifically an all-solid state solar cell, and to make a CdS film by using a high number (20 - 40) of successive coating processes, the aim of Siebentritt et al. **is not** to produce quantum dots, but to produce a film "**of reasonable thickness**" (see left column, lines 9 to 11, p. 1824).

The Applicants submit that it is not correct to state merely that "Siebentritt does not expressly disclose that the deposition treatment for the quantum dot particles can be performed 2 to 10 times." Siebentritt et al. goes far beyond. It expressly teaches **away** from the teaching of Vogel, since, with knowledge of the teaching of Vogel, Siebentritt et al. teaches to repeat the coating process a number of times sufficient to grow the particles far beyond the quantum dot size, so that they merge to films. Siebentritt et al. further discloses an annealing process such that the dimensions of the crystallites within the amorphous semi-conductor matrix also grow bigger, thereby obtaining an improvement

of the photoresponse in the visible region, with a maximum quantum efficiency of 12 %  
(see p. 1825, right column, second paragraph of the Siebentritt et al. reference).

In other words, whereas there exists on one hand a basic teaching of Vogel disclosing how to make quantum dots on a TiO<sub>2</sub> substrate, and also how to make them grow bigger and merge, at a later point in time the Siebentritt et al. reference, within the framework of efforts towards an all-solid state solar cell, teaches away from making quantum dots by the process of Vogel. Thus, the Applicants submit that the claimed invention is by no means obvious over Siebentritt et al. in view of Vogel, because Siebentritt et al. teaches away from the quantum dot range taught by Vogel.

In view of the above, the Applicants submit that the invention claimed in proposed amended claim 1 is patentably distinguishable over the prior art made of record. Entry of and a favorable reconsideration of claim 1 under Rule 116, and also of all the other claims, since all these are depending upon or linked to proposed amended claim 1, is respectfully requested.

Attached hereto are pages 10 and 11 that present a marked up version of the proposed changes to be made to the claims of the application by the current Rule 116 Amendment. Page 10 is captioned "VERSION WITH MARKINGS TO SHOW CHANGES MADE."

Respectfully submitted

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**VERSION WITH MARKINGS TO SHOW CHANGES MADE**

**Claim 4 has been canceled and claims 1, 9, 14, 15, 16 and 17 have been amended as follows:**

1. (Twice amended) A solid state p-n heterojunction comprising an electron conductor in the solid state and a hole conductor, further comprising a sensitising semiconductor, said sensitizing semiconductor being located at an interface between said electron conductor and said hole conductor, characterised in that said hole conductor is in the solid state, in that said sensitizing semiconductor is in a form consisting of individual particles adsorbed at the surface of said electron conductor, said individual particles being quantum dots, and in that said p-n heterojunction comprises a plurality of individual point-contact heterojunctions between said quantum dots and said electron conductor and said hole conductor.

9. (Amended) A heterojunction as claimed in claim 1, characterised in that said hole conductor is an amorphous reversibly oxydisable organic or [organomethallic] organometallic compound.

14. (Amended) A solid state sensitized photovoltaic cell comprising a [layered] solid state p-n heterojunction as claimed in claim 1.

15. (Amended) A cell as claimed in claim 14, characterised in that it comprises

a transparent first electrode,

a said [layered] solid state p-n heterojunction and

a second electrode.

16. (Amended) A cell as claimed in claim 15, further comprising a dense semiconductive layer between said first electrode and said [layered] solid state p-n heterojunction.

17. (Amended) A cell as claimed in claim 14, characterised in that said [layered] solid state p-n heterojunction is obtained by forming quantum dots on the surface of said electron conductor by at least one deposition treatment, before providing said hole conductor to said layered heterojunction.